CLAIMS

1. A process for the regeneration of a deactivated zeolite beta catalyst comprising:

(a) providing a catalyst bed of a zeolite beta hydrocarbon conversion catalyst which has been deactivated in a hydrocarbon conversion reaction by the deposition of coke on the zeolite beta catalyst, said coke having a porosity characteristic ranging from a relatively porous coke constituent to a relatively less porous refractory coke constituent;

(b) heating said zeolite beta to an elevated temperature in excess of 300°C in an inert environment which is substantially free of oxygen;

(c) thereafter supplying an oxidative regeneration gas comprising a mixture of an oxygen containing gas and an inert gas through said catalyst bed to oxidize at least a portion of the relatively porous coke component at a temperature greater than the temperature in subparagraph (b) and produce an exotherm which moves through said catalyst bed;

(d) continuing the passage of said regeneration gas through said catalyst bed to result in decoking of said zeolite catalyst within said bed while progressively increasing at least one of the temperature and the oxygen content of said regeneration gas to oxidize a less porous component of said coke with the production of an exotherm which passes through said catalyst bed;

(e) thereafter supplying a regeneration gas comprising a mixture of an oxygen containing gas and an inert gas having at least an increased oxygen content or an increased temperature greater than the temperature or oxygen content in subparagraph (d) to oxidize a less porous refractory component of said coke; and

(f) thereafter further diminishing the oxygen content of said regeneration gas and passing an inert gas through said catalyst bed at a reduced temperature.

2. The method of claim 1 wherein the ratio of oxygen-containing gas to inert gas is progressively increasing in the course of the operation of subparagraph (d).

3. The method of claim 2 wherein the oxygen-containing gas is air and the inert gas is nitrogen.

4. The method of claim 3 wherein the air content of said regeneration gas is progressively increased until the air content is within the range of 40-60 vol.%.

5. The method of claim 4 wherein said regeneration gas is introduced into said catalyst bed at a temperature of at least 500°C and has an initial air content of no more than 5 vol.%.

6. The method of claim 1 wherein said zeolite beta catalyst is a rare earth promoted zeolite beta.

7. The method of claim 6 wherein said zeolite beta catalyst is promoted with lanthanum or cerium.

8. The method of claim 7 wherein said zeolite beta catalyst is a cerium promoted zeolite beta.

9. The method of claim 8 wherein said cerium promoted zeolite beta catalyst has a silica/alumina mole ratio within the range of 50-200.

10. The process of claim 9 wherein said catalyst has a cerium/aluminum atomic ratio

within the range of 0.5-1.5.

11. The method of claim 1 wherein said zeolite beta catalyst in the catalyst bed of subparagraph (a) has been deactivated by use of the catalyst in the reaction of a C_2-C_4 alkylating agent with an aromatic substrate.

12. The method of claim 11 wherein said alkylating agent is ethylene or propylene, and said aromatic substrate is benzene.

13. The method of claim 11 wherein said alkylating agent is ethylene and said aromatic substrate is benzene.

14. The process of claim 1 further comprising subsequent to subparagraph (d) and prior to subparagraph (e) introducing an inert gas into said reaction zone at a temperature greater than the temperature in subparagraph (b).

15. The process of claim 14 wherein said inert gas introduced into said reaction zone is at a temperature of at least 50°C greater than the temperature in subparagraph (b) of claim 1.

16. A process for the production of ethyl benzene over a zeolite beta alkylation catalyst and the regeneration of said catalyst comprising:

(a) providing an alkylation reaction zone incorporating a catalyst bed of a zeolite beta alkylation catalyst;

(b) supplying an aromatic feed stock containing benzene into said catalyst bed at an inlet side of said reaction zone;

(c) supplying ethylene to the inlet side of said reaction zone and into contact with said catalyst bed;

(d) operating said alkylation reaction zone at temperature and pressure conditions in which benzene is in the gas phase, the liquid phase or the supercritical phase to cause ethylation of said benzene by an exothermic reaction in the presence of said zeolite beta alkylation catalyst with the production of an exotherm which passes through said catalyst bed in a direction from the inlet of said reaction zone to the outlet of said reaction zone;

(e) continuing the supply of said aromatic substrate and ethylene to said reaction zone until said exotherm traverses a substantial portion of the catalyst bed;

(f) thereafter terminating the supply of ethylene and benzene to said reaction zone; and introducing an inert gas into said reaction zone to provide temperature conditions in said reactor which initially are lower than the temperature conditions of subparagraph (d);

(g) increasing the temperature in said reaction zone and initiating the supply of an oxidative regeneration gas comprising a mixture of oxygen and said inert gas through said catalyst bed to oxidize said coke and produce an exotherm which moves through said catalyst bed;

(h) continuing the passage of said regeneration gas through said catalyst bed to result in decoking of said zeolite catalyst within said bed until the exotherm passes through a substantial portion of the bed;

(i) thereafter supplying a regeneration gas comprising a mixture of oxygen and inert gas having an increased ratio of oxygen to the inert gas to oxidize said coke at an increased temperature greater than the temperature in subparagraph (g); and

(j) thereafter further diminishing the oxygen content of said regeneration gas and passing on inert gas through said catalyst bed at a reduced temperature.

17. The process of claim 16 wherein said alkylation reaction zone is operated at temperature and pressure conditions in which said benzene is in the liquid phase or supercritical phase.

18. The process of claim 16 wherein said inert gas and said oxidative regeneration gas are introduced into said reaction zone in which flow is from the direction of the outlet of said reaction zone to the inlet of said reaction zone in a direction counter current to the flow of said aromatic feed stock and said ethylene.

19. The process of claim 16 wherein the supply of ethylene in subparagraph (f) is terminated prior to the supply of benzene.

20. The method of claim 16 wherein the oxygen containing gas is air and the inert gas is nitrogen.

21. The method of claim 20 wherein said zeolite beta catalyst is promoted with lanthanum or cerium.

22. The method of claim 21 wherein said zeolite beta catalyst is a cerium promoted zeolite beta.

23. The method of claim 22 wherein the air content of said regeneration gas is progressively increased until the air content is within the range of 40-60 wt.%.

24. The method of claim 23 wherein said regeneration gas is introduced into said catalyst bed at a temperature of at least 500°C and has an initial air content of no more than 5 wt.%.

25. A process for the production of ethyl benzene over a cerium promoted zeolite beta alkylation catalyst and the regeneration of said catalyst comprising:

(a) providing an alkylation reaction zone incorporating a catalyst bed of a cerium promoted zeolite beta alkylation catalyst;

(b) supplying an aromatic feed stock containing benzene into said catalyst bed at an inlet side of said reaction zone;

(c) supplying ethylene to the inlet side of said reaction zone and into contact with said catalyst bed;

(d) operating said alkylation reaction zone at temperature and pressure conditions in which benzene is in the gas, liquid phase or supercritical phase to cause ethylation of said benzene by an exothermic reaction in the presence of said cerium promoted zeolite beta catalyst with the production of an exotherm which passes through said catalyst bed in a direction from the inlet of said reaction zone to the outlet of said reaction zone;

(e) continuing the supply of said aromatic substrate and ethylene to said reaction zone until said exotherm traverses a substantial portion of said catalyst bed and said catalyst is deactivated by the disposition of coke thereon and thereafter terminating the supply of ethylene and benzene to said reaction zone;

(f) introducing nitrogen into said reaction zone and continuing the injection of nitrogen into said reaction zone until the benzene content within said reaction zone is substantially reduced;

(g) thereafter initiating the supply of an oxidative regeneration gas comprising a mixture of oxygen and nitrogen at an elevated temperature through said catalyst bed to oxidize the coke on said catalyst bed and produce an exotherm which moves through said catalyst bed concurrently with the flow of said mixture of oxygen and nitrogen through said catalyst bed;

(h) continuing the passage of said regeneration gas through said catalyst bed to result in decoking of said cerium promoted zeolite beta catalyst until the exotherm passes through a substantial portion of the catalyst bed;

(i) thereafter supplying nitrogen to said catalyst bed at a temperature greater than the temperature in subparagraph (g) to provide an incremental increase in the average temperature of said catalyst bed;

(j) thereafter supplying a regeneration gas comprising a mixture of oxygen and nitrogen at a temperature greater than the temperature in subparagraph (g) to oxidize coke on said catalyst bed and produce an exotherm having a temperature greater than the temperature of the exotherm in subparagraph (g) and continuing the passage of said regeneration gas until said exotherm passes through a substantial portion of the catalyst bed;

(k) thereafter introducing nitrogen into said catalyst bed, and continuing the injection of said nitrogen at an elevated temperature greater than the temperature in subparagraph (i);

(l) thereafter supplying a regeneration gas comprising a mixture of air and nitrogen to oxidize coke in said catalyst bed to produce an exotherm having a temperature greater than the exotherm temperature in subparagraph (j); and

(m) thereafter reinstituting the operation of said reaction zone for the production of ethylbenzene by introducing benzene and ethylene to the inlet of said reaction zone.

26. The process of claim 25 wherein said alkylation reaction zone is operated at temperature and pressure conditions in which said benzene is in the liquid phase or supercritical phase.

27. The process of claim 26 wherein said inert gas and said oxidative regeneration gas are introduced into said reaction zone in which flow is from the direction of the outlet of said reaction zone to the inlet of said reaction zone in a direction countercurrent to the flow of said aromatic feed stock and said ethylene.

28. The process of claim 27 wherein said cerium promoted zeolite beta alkylation catalyst has a silica alumina mole ratio within the range of 50-200.

29. The process of claim 28 wherein said catalyst has a cerium/aluminum atomic ratio within the range of .5-1.5.

30. The process of claim 26 further comprising subsequent to subparagraph (l) and prior to subparagraph (m) introducing nitrogen into said catalyst bed at a temperature less than the temperature of subparagraph (k).

31. The method of claim 26 wherein the temperature differential between the supply

of nitrogen in subparagraphs (f) and (i) is greater than the increase in temperature in nitrogen between the nitrogen temperature and subparagraph (i) and subparagraph (k).

32. A process for the alkylation of an aromatic substrate with a C2-C4 alkylating agent over a rare earth promoted zeolite beta alkylation catalyst and the regeneration of said catalyst comprising:

(a) providing an alkylation reaction zone incorporating a catalyst bed of a rare earth promoted zeolite beta alkylation catalyst;

(b) supplying an aromatic feed stock containing said aromatic substrate into said catalyst bed at an inlet side of said reaction zone;

(c) supplying a C2-C4 alkylating agent to the inlet side of said reaction zone and into contact with said catalyst bed;

(d) operating said alkylation reaction zone at temperature and pressure conditions in which said aromatic substrate is in the gas phase, the liquid phase or the supercritical phase to cause alkylation of said aromatic substrate by an exothermic reaction in the presence of said zeolite beta alkylation catalyst with the production of an exotherm which passes through said catalyst bed in a direction from the inlet of said reaction zone to the outlet of said reaction zone;

(e) continuing the supply of said aromatic substrate and said alkylating agent to said reaction zone until said exotherm traverses a substantial portion of the catalyst bed and said catalyst is deactivated by the deposition of coke thereon;

(f) thereafter terminating the supply of said alkylating agent and said aromatic substrate to said reaction zone and introducing an inert gas into said reaction zone at an elevated temperature to provide an inert environment which is substantially free of oxygen;

(g) initiating the supply of an oxidative regeneration gas comprising a mixture of an oxygen-containing gas and said inert gas through said catalyst bed to oxidize said coke and produce an exotherm which moves through said catalyst bed;

(h) continuing the passage of said regeneration gas through said catalyst bed to result in decoking of said zeolite catalyst within said bed while progressively increasing at least one of the temperature and the oxygen content of said regeneration gas to oxidize a portion of the coke deposited on said catalyst with the production of exotherm which moves through said catalyst;

(i) thereafter supplying a regeneration gas comprising a mixture of oxygen containing gas and inert gas having at least one of an increased oxygen content or an increased temperature greater than the temperature or oxygen content in subparagraph (h) to oxidize an additional portion of the coke deposited on said catalyst; and

(j) thereafter diminishing the oxygen content of said regeneration gas and passing an inert gas through said catalyst bed at a reduced temperature.

33. The process of claim 32 wherein said alkylation reaction zone is operated at temperature and pressure conditions in which said aromatic substrate is in the liquid phase or supercritical phase.

34. The method of claim 33 wherein said oxygen-containing gas is air and the inert gas is nitrogen.

35. The method of claim 34 wherein said rare earth promoted zeolite beta is cerium promoted zeolite beta.

36. The method of claim 35 where in the oxidative regeneration gas is introduced into

said catalyst bed at a temperature of at least 500°C, and initially exhibits an air content of no more than five volume percent and is thereafter progressively increased until the air content of said regeneration gas is within the range of 40-60 volume percent.

37. The method of claim 35 wherein said cerium promoted zeolite beta catalyst has a silica/alumina mole ratio within the range of 50-200 and a cerium/aluminum atomic ratio within the range of 0.5-1.5.